Hon W. Patterson

BULLETIN No. 163. DECEMBER, 1899.

New York Agricultural Experiment Station.

GENEVA, N. Y.

THE NEW YORK APPLE-TREE CANKER.

WENDELL PADDOCK.

PUBLISHED BY THE STATION.

BOARD OF CONTROL.

GOVERNOR ROOSEVELT, Albany.
WILLIAM C. BARRY, Rochester, Monroe Co.
S. H. HAMMOND, Geneva, Ontario Co.
MARTIN V. B. IVES, Potsdam, St. Lawrence Co.
A. C. CHASE, Syracuse, Onondaga Co.
F. O. CHAMBERLAIN, Canandaigua, Ontario Co.
F. C. SCHRAUB, Lowville, Lewis Co.
NICHOLAS HALLOCK, Queens, Queens Co.
LYMAN P. HAVILAND, Camden, Oneida Co.
G. HOWARD DAVISON, Millbrook, Dutchess Co.

OFFICERS OF THE BOARD.

MARTIN V. B. IVES, *President.*

W. O'HANLON, *Secretary and Treasurer.*

EXECUTIVE COMMITTEE.

S. H. HAMMOND,
W. C. BARRY,
F. O. CHAMBERLAIN,
F. C. SCHRAUB,
LYMAN P. HAVILAND,
G. HOWARD DAVISON.

STATION STAFF.

W. H. JORDAN, SC. D., *Director.*

GEO. W. CHURCHILL, *Agriculturist and Superintendent of Labor.*

WM. P. WHEELER, *First Assistant (Animal Industry).*

F. C. STEWART, M. S., *Botanist.*

F. H. BLODGETT, M. S., *Assistant Botanist and Entomologist.*

F. M. ROLFS, B. S., *Student Assistant in Botany.*

L. L. VAN SLYKE, PH. D., *Chemist.*

C. G. JENTER, PH. C.,
*W. H. ANDREWS, B. S.,
J. A. LECLERC, B.S.,
*A. D. COOK, PH.C.,
FRED D. FULLER, B.S.,
E. B. HART, B.S.,
*CHAS. W. MUDGE, B. S.,
Assistant Chemists.

H. A. HARDING, M. S., *Dairy Bacteriologist.*

L. A. ROGERS, B.S., *Student Assistant in Bacteriology.*

GEO. A. SMITH, *Dairy Expert.*

FRANK H. HALL, B. S., *Editor and Librarian.*

VICTOR H. LOWE, M. S.,
†F. A. SIRRINE, M. S.,
Entomologists.

S. A. BEACH, M. S., *Horticulturist.*

WENDELL PADDOCK, B. S., *Assistant Horticulturist.*

FRANK E. NEWTON,
JENNIE TERWILLIGER,
Clerks and Stenographers.

A. H. HORTON, *Computer.*

Address all correspondence, not to individual members of the staff, but to the NEW YORK AGRICULTURAL EXPERIMENT STATIO[N], GENEVA, N. Y.

The Bulletins published by the Station will be sent free to any farm[er] applying for them.

---

*Connected with Fertilizer Control.
†Connected with Second Judicial Department Branch Station.

BULLETIN No. 163.

THE NEW YORK APPLE-TREE CANKER.

WENDELL PADDOCK.

SUMMARY.

Attention has but recently been called to this canker of apple trees, probably because the injuries were thought to be due entirely to sun scald.

Experiments extending through two seasons prove that this canker is caused by attacks of *Sphaeropsis malorum* Pk. (see p. 202), the fungus that causes the black rot of apple, pear, and quince fruits. The experiments also indicate that this fungus occurs on a number of other plants.

This disease is widely distributed in the orchards of the State as well as in those of adjacent States. In many instances it has been very destructive.

By way of treatment it is recommended: That the trees be kept in the best growing condition; that cankered limbs be removed where practicable; that the trees be sprayed with Bordeaux mixture as recommended on page 190; and that in some instances the trunks and larger limbs be scraped and washed as recommended on page 190.

CANKER.—WHAT IS IT ?

The term canker, as applied to plant diseases, has been in use in Europe for a long time, where it is commonly used to designate the injury done to trees by species of *Nectria*. (See Plate VI, fig. 2.) In fact the *Nectrias* have been associated with such injuries so long that in some instances the word canker has come to be regarded as a specific rather than a general term, but other species of fungi may cause a cankered condition of trees and plants. According to Hartig such wounds may be produced by the action of frost, when they are called frost cankers. In general, then, it may be said that any injury of trees, whereby a portion of the bark is destroyed and the wood laid bare may be classified under the general term, canker.

That the term canker, as applied to plant diseases, is new to many of our fruit growers may be due to the fact that the *Nectrias* are of but little economic importance in the United States.

THE NEW YORK APPLE-TREE CANKER[1].—HISTORY.

Orchardists have been familiar with this diseased condition of of the limbs of the apple tree for years. This is especially true with the Esopus Spitzenberg, where the injury to the limbs, commonly thought to be due entirely to sun-scald, has been associated with the apparent running out of this favorite apple. Attention was first called to the probability of this injury being caused by a plant disease by M. B. Waite, of the U. S. Department of Agriculture, Washington, D. C., in an article[2] that was read at the meeting of the Western New York Horticultural

[1] The name New York Apple-Tree Canker is proposed for this disease for the purpose of distinguishing the canker produced by the attacks of the fungus *Sphæropsis malorum* Pk. (see page 202) from cankers that are due to the action of other fungi, as the Pacific Coast Apple-Tree Canker and the European Canker.

[2] Waite. Proceedings Western N. Y. Hort. Soc., 1898, pp. 9, 10. A brief article, included in the report of the committee on botany and plant diseases, notes prevalence of an apple-tree canker in orchards of Western New York.

Society in 1898 and which appeared a few days later in the *Rural New Yorker*[3]. Mr. Waite suggested the fungus *Schizophyllum commune* Fr. as the probable cause of the disease. This article, together with notes[4] and a paper[5] by the writer, and a poster bulletin[6], is the extent of the bibliography on the subject.

INVESTIGATIONS IN 1898.

In the spring of 1898 the Chapin Brothers, of East Bloomfield, N.Y., requested the Experiment Station authorities to investigate the cause of the dying of trees in their orchard. Prof. Beach visited the orchard and saw at once that a canker was the cause of the trouble, the serious nature of which was plainly evident in the numerous dead and dying trees. The writer was detailed to work on the subject, and the history of the investigations, extending through two seasons, is herewith presented.

The orchard in question originally consisted of one hundred and twenty-five acres. The trees on thirty of the eighty acres in one part were ruined by the canker and have been taken out, and the trees on one-half of the remaining fifty acres are now of little value. In the other part of the orchard originally consisting of forty-five acres, only about ten acres are left that are of much value. The owners have noticed the disease for the past six or eight years, but it has increased very rapidly in the last three or four years. They have also found that it shows a decided preference for certain varieties, the Twenty Ounce being the most susceptible ; then the Baldwin, Wagener, Greening and King follow in the order named. The Tallman Sweet appears to be practically free from the disease. Trees growing in low land or in any

---

[3] Waite. *Rural New Yorker*, Feb. 5, 1898, p. 82.

[4] Paddock. *Science*, **8** : 596. An Apple Canker. Brief account of investigations, and concludes that the disease is probably caused by the fungus *Sphæropsis malorum* Pk.

——— P. 836. Additional Notes on an Apple Canker. Notes the occurrence of a *Sphæropsis* on pear and quince trees, and as causing a twig blight of apple trees.

[5] Paddock. Proceedings of the Western N. Y. Hort. Soc. 1899, pp. 58–64. An Apple Canker. Popular account of investigations with the disease.

[6] Vermont Special Bulletin, April, 1899, gives illustrations of cankered apple-tree limbs.

situation where the ground was at all wet, were found to suffer most, while the trees in the outside rows were noticeably freer from the canker than those in less exposed situations.

It has been argued by some persons that the trees, now forty years old, have reached the limit of their usefulness and are dying of old age. However, those trees that are free from canker are in a very vigorous condition, and the fact that cankered limbs occur on much younger trees in widely separated localities and in the best orchards, tends to disprove this theory. Neither can the trouble in this case be attributed to neglect, unless it be in the matter of spraying, since the orchard has received from the beginning practically the same culture that is advocated by our best authorities of to-day. Sixteen years ago the orchard was thinned by taking out each alternate diagonal row of trees. The elder Mr. Chapin was one of the first to spray with insecticides, but the all important point, as it now appears, spraying with Bordeaux mixture, has been neglected. An apparent contradiction to this statement is found in an old orchard not a quarter of a mile distant, that has never been sprayed and has been in sod for years, yet there are very few cankered limbs in any of the trees. It may be mentioned, however, that this orchard is located on a different slope of land and on poorer soil. The soil of the Chapin orchard is for the most part deep and rich and has produced a vigorous growth so that now the trees are very large.

Severe and unintelligent pruning has also been given as the cause of the presence of canker in this as well as other orchards. While it is admitted that misuse of any kind may favor the development of the canker fungus indirectly, yet the answer to the specific statement is found in the fact that unpruned seedling apple trees are found in wood pastures that are badly attacked by the canker fungus.

In the preliminary studies of the canker certain large, dark colored spores were found, which were at the time supposed to come from some saprophyte; however, cultures were made from them. Agar plate cultures were also made from the diseased bark, by taking small particles from the inner bark with sterile instruments. Two forms of fungi appeared in these cultures more or less constantly, which led to their being separated and

transferred to sterilized bean stems in test tubes. Here they grew luxuriantly and soon produced fruit, the one form producing the familiar dark colored spores which was not at that time identified, while in the other the sporophores of *Schizophyllum commune* Fr. were formed.

Inoculations were made with the cultures on June 22 on seedling apple trees in the nursery row as follows: Three trees were inoculated with material from cultures of the dark spored fungus, three trees with material from cultures of *Schizophyllum commune*, and three trees were punctured but not inoculated to serve as checks. The inoculations were made by cutting a small opening in the bark with a sterilized knife and inserting a small amount of the material from the bean stem cultures between the bark and wood. All of the punctures were covered with filter paper which was kept moist for about thirty-six hours. On the same date two inoculations with each of the two cultures together with check wounds were made in the larger limbs of a mature apple tree. These inoculations were not moistened or protected in any way. In two weeks' time there was an area of discolored bark around each place of inoculation where the unknown fungus had been inserted. The other inoculations as well as the checks showed no signs of growth and the wounds soon healed.

As soon as it was known that the one fungus could penetrate living bark under certain conditions more inoculations were made. July 6, six young seedling apple trees in the nursery row and three limbs of a large apple tree were inoculated with the dark spored fungus, six seedling nursery trees and three limbs of a larger tree with *Schizophyllum commune* while three seedling nursery trees and three limbs of a large tree were punctured but not inoculated to serve as checks. The inoculations made in the seedling trees were all protected with filter paper as before, but those made in the larger tree were unprotected. The dark spored fungus grew at all points of inoculation, while all of the other wounds soon healed.

On July 11 an effort was made to imitate the scars that are found in the outer bark that are mentioned on page 187. Small pieces of the outer bark were cut from two small areas on separate limbs of a large tree which were inoculated with the dark

spored fungus, making twenty-eight inoculations in all. Two similar areas were inoculated with *Schizophyllum commune* and two areas were prepared but not inoculated to serve as checks.

Ten inoculations with the dark spored fungus, two with *Schizophyllum commune* and two check wounds were made by cutting through to the wood as before. All inoculations and check wounds were kept moist with damp filter paper. The dark spored fungus grew at all points of inoculation producing deep wounds or cankers where the incisions were made through to the wood as is shown in Plate III, fig. 3. Fig. 1 of the same plate shows the effect of the inoculations where small pieces of the outer bark were removed. The fungus was unable to penetrate to the cambium and made only small surface wounds, as may be seen in the illustration. The pieces of bark have been removed on one side leaving scars which resemble those that occur on cankered limbs as in Plate III, fig. 2.

On the same date, July 11, four inoculations were made w th each of the two cultures in the larger limbs of a pear tree and four of each in the larger limbs of a quince tree. The inoculations, together with check wounds, were kept moist with damp filter paper as before. The dark spored fungus grew at all points of inoculation on the pear tree but did not grow on the quince. All of the inoculations with *Schizophyllum commune* together with check wounds soon healed.

These experiments showed conclusively that the dark spored fungus can penetrate living apple-tree bark under certain conditions and produce a cankered condition of apple-tree limbs and also indicated that it may produce a diseased condition of pear-tree bark. On the other hand it is evident that *Schizophyllum commune* Fr. cannot penetrate living apple-tree bark and it is quite probable that the same is true of pear-tree bark. The result of the inoculations on the quince cannot be regarded as conclusive because of the small number of inoculations made; but numerous inoculations made in the spring of 1899 showed that the dark spored fungus can produce a cankered condition of quince limbs when inserted under the bark.

The stress of other duties during the growing season prevented any study into the nature of the canker fungus and nothing further

was done until fall when cultures of the fungus were shown to Mr. F. C. Stewart, the Station Botanist. He at once noted a strong resemblance of the dark spores to those of the black rot of the apple, *Sphæropsis malorum* Pk., and suggested that it might be that disease. Mature apples were at once inoculated with material from the test tube cultures that had been obtained from cankered apple-tree limbs. In twenty-four hours decay had begun around the points of inoculation and in sixteen days pycnidia and mature spores of *Sphæropsis* were found on all inoculated apples. The check apples which were punctured but not inoculated and kept under the same conditions remained sound. This experiment was repeated many times and the results were always the same.

Now that it was known what to look for an examination of cankered limbs in the orchard revealed the presence of an abundance of small, dark, fungus pustules or pycnidia on the brown and shrunken areas of dead bark. Fig. 3 of Plate I is a larger view of the smaller canker shown in Fig. 1 at *b*. An examination of the bark on the older portion of the cankered area reveals the presence of numerous pycnidia in which the dark colored spores, that have been frequently mentioned, are borne. They are shown natural size in Fig. 4, which is a small section of the dead bark from the same canker. It will be seen that the pycnidia are abundant and large enough to be easily found.

Pycnidia containing mature spores were also found to be abundant on the dead bark surrounding the points of inoculation that were made from the cultures of *Sphæropsis*. Plate III, fig. 3, is from a photograph of one of the limbs of an apple tree as it appeared at the close of the present season, that was inoculated in the spring of 1898 with cultures made from a cankered limb. Pycnidia are numerous on the surface of the bark and on the decorticated wood as well.

The result of over fifty inoculations made from cultures that were obtained from cankered apple tree limbs prove that the apple-tree canker of New York apple orchards is caused by a fungus of the genus *Sphæropsis*. In every instance where the incisions were made through to the wood, typical cankers were produced and mature fruit of the *Sphæropsis* formed on the decay-

ing bark and in some instances on the decorticated wood also. The inoculation experiments were repeated many times during the season of 1899 and the results have been the same.

GEOGRAPHICAL DISTRIBUTION.

A personal examination of a great many orchards during the past two seasons reveals the fact that this canker of apple trees is widely distributed in the orchards of New York. In fact an orchard is rarely seen that is entirely free from the disease. As is to be expected, however, it is more abundant in some localities than in others, and as has been previously mentioned, some varieties are more subject to the disease than others. It is specially injurious in many of the apple growing sections of western New York.

Responses to a circular letter sent to the authorities of the various experiment stations together with personal examinations bring out the positive information that this canker occurs in Connecticut, Indiana, Maryland, Michigan, Pennsylvania and Vermont, and that it probably occurs in Illinois, Maine, Massachusetts, Minnesota, New Jersey, West Virginia and portions of Canada. It seems probable that when the disease becomes more generally known it will be found in many of the apple growing sections of the northern, central, and New England states.

APPEARANCE OF CANKERED LIMBS.

When one approaches a diseased tree his attention will be attracted to the dark and enlarged sections of the larger limbs. A closer examination shows that the bark is much roughened as well as thickened, and in many instances a portion of the wood is laid bare. The decaying bark and wood offer a convenient lodging place for borers and fungi which aggravate the injury and add to its unsightly appearance. The dead bark on many of the diseased limbs clings tenaciously to the decaying wood, which is a feature that distinguishes this canker from sun scald, since with the latter trouble usually the first symptom to be noticed is the peeling of the bark from the injured surface. The area of bare wood is often small as compared to the extent of swollen bark ; limbs are frequently seen that for six feet or more of their

length are covered with rough bark. The progress of the disease on such limbs may be marked by numerous pits or scars, showing where the fungus was able to live until perchance it gained entrance to the cambium through some injury, when a serious wound was the result. These scars are usually circular in form and may be outlined by two or more concentric lines. An example of this form of the disease is shown in Fig. 1 of Plate II, where for more than six feet of its length the limb is covered with the rough bark or the scars where the bark has become detached. The fungus has only reached the cambium and formed a canker at *a*. Fig. 2 of Plate III is a larger view of a section of the same limb showing the scars more in detail.

Other instances occur, where, though the bark is much swollen and roughened, the fungus has not been able to penetrate to the cambium, but has died after a time leaving the scars of its attack, aside from which the limb has regained its normal condition.

The fungus shows a preference for the larger limbs of mature trees. Small limbs and young trees are much less frequently attacked, though the trunks and branches of the latter are sometimes badly injured, and twigs of the current season's growth may suffer serious injury from attacks of the fungus. Twenty Ounce apple trees are apparently the exception, since in some localities the trunks of this variety are badly injured. The fungus extends down from diseased branches or from canker spots at the forks of the tree till in aggravated cases large areas of bark are destroyed exposing the wood in ugly wounds. These patches of black, decaying wood are conspicuous from a distance. Old age and neglect, or a lack of vigor from any cause evidently favor the disease though apparently thrifty trees are frequently ruined by its attack.

The effect of a canker on a limb depends on the amount of bark that is injured or destroyed. In severe cases the disease may extend entirely around a limb, thus effectually girdling it. Thus it occasionally happens that the leaves on some part of a tree shrivel and die without apparent cause, but a close examination shows the presence of rough, dead bark somewhere on the limb, indicating the presence of the canker fungus which has extended around the limb and cut off the flow of sap.

Plates I and II are reproduced from photographs of typical cankered limbs. In Fig. 1 of Plate I the characteristic rough bark is shown and at *a* the wood is exposed, the white fruiting bodies of the fungus, *Schizophyllum commune* Fr., being conspicuous on the dead bark. At *b* is a canker spot of comparatively recent formation. Fig. 2 shows the same limb from which the dead bark has been removed ; only a narrow strip of live bark remained that kept the limb alive. Fig. 3 is an enlarged view of the more recent canker shown in Fig. 1 at *b*. This canker is evidently of three season's growth as is indicated by the three series of concentric lines, now rather indistinct, that at one time separated the dead from the living bark. The extent of the current season's growth can be readily distinguished by the smoother appearance, while a distinct line separates the dead from the living bark.

In some instances cankers occur quite uniformly on the southwest side of the trees thus indicating that they had their origin in injuries produced by sun scald. The work of the fungus may be recognized by the thick rough bark, while the fruiting pustules reveal its presence where it is still or has recently been in an active condition.

EXTENT OF INJURY.

The extent of injury done to the orchards of the State can scarcely be estimated, but it is safe to say that this canker is one of the worst diseases with which the orchardist will have to contend since it attacks the tree directly instead of the foliage and fruit as is the case with the majority of our orchard diseases. The appearance of the cankers is such that their injurious nature may not be apparent to the casual observer until his attention is attracted by the shrivelling of the leaves ; thus the tree may be ruined before it is realized that anything serious is the matter. In one instance the loss of a large acreage of orchard was due to the attacks of the canker fungus (see page 181) and in a great many orchards it has done serious damage.

TIME AND MANNER OF INFECTION.

Infection takes place in the spring of the year as is shown by the growth that the fungus makes in the bark. The presence of

the fungus in a newly infected limb is first indicated by a small area of discolored bark. This area extends slowly as the fungus grows outward in all directions till mid-summer, when a definite boundary forms between the dead and living bark thus showing that growth for the season has stopped. This season's growth had stopped by the first of August, and in some instances pycnidia containing mature spores were found at that time on bark where infection had taken place in the spring.

Many of the spores remain in the pycnidia till the following spring, or longer, when they are given off and disseminated. The mycelium is unable to penetrate to the cambium through living bark, but those spores that chance to fall and germinate in a wound, produce the cankers. Other spores are deposited on limbs that have an abundance of dead and decaying outer bark where they find conditions suitable for growth. In such instances no direct injury is done to the tree, but spores are produced and disseminated so that a constant source of infection is maintained. The spores possess great vitality since some of them germinate after having been kept a year in the laboratory.

In some instances the mycelium apparently lives over winter and continues its growth the following spring. The formation of the largest cankers can scarcely be explained in any other way. However, in all of the inoculations made in the spring of 1898, in only one instance did the resulting canker enlarge any during the present season. See Plate III, fig. 3.

DOES THE MYCELIUM PENETRATE THE WOOD?

This question is suggested by the presence of two or more cankers on the same limb, the external appearance of the more recent ones suggesting the possibility of the fungus having passed from the older canker through the wood and appearing on the surface of the limb at favorable points where the newer cankers were formed. An examination of a number of specimens and the occurrence of pycnidia on decorticated wood shows that while the mycelium does penetrate the wood to some extent, the fact is of little economic importance. One limb was examined that had five small cankers on it at intervals of about a foot. On split-

ting the limb it was found that the mycelium had penetrated the wood at but one point and that for only a short distance.

PREVENTIVE MEASURES.

Although experiments in treating this disease are under way no results have yet been reached and from the nature of the fungus it will be seen that a number of years must elapse before data can be secured from which definite conclusions may be drawn. However it is a matter of common observation that in the majority of instances the disease is not nearly as prevalent in orchards that have been well sprayed with Bordeaux mixture for several years past as it is in those that have not been sprayed. Judging from the success with which many other plant diseases are combated it is reasonable to expect beneficial results to follow systematic spraying with Bordeaux mixture as a preventive of the canker.

In localities where canker is abundant special attention should be paid to the sanitary condition of the trees. Perhaps one of the most important considerations is to see that the trees are not crowded and that they are pruned so as to admit sunshine and a free circulation of air. The old bark is not shed as freely from the limbs and trunks of trees that are densely shaded and the moisture collecting in this bark is not easily dried out; thus faculative parasites like the canker fungus as well as saprophytic fungi find congenial surroundings.

The practice of scraping and whitewashing the trunks and branches of fruit trees has largely fallen into disfavor but it is certainly a commendable practice and should be adopted in localities where canker is severe. However washes that are less conspicuous and equally if not more effective than whitewash are now recommended; the following formula has been satisfactory to some orchardists:

WASH FOR TREE TRUNKS.

Whale oil soap	1 pint.
Slaked lime	3 pints.
Water	4 gallons.
Wood ashes	to thicken as desired.

Dissolve the soap in hot water, then stir in the lime. When the ingredients have been reduced to a smooth state by stirring

dilute with water to four gallons, then stir in wood ashes till the wash is of the desired consistency.

Other formulæ equally as good as the one given are in use, but the important ingredients in most of them are the same as in the one given above.

These washes probably have the effect of softening and loosening the old bark so that it is more readily shed, thus relieving the bark bound condition and inducing a vigorous growth. Bordeaux mixture is beneficial in this respect as a smooth, shiny appearance of the bark is a characteristic of well sprayed trees.

A discussion of the necessity of thorough cultivation and fertilization of orchards need not be entered into here, but it may be said that any treatment that tends to promote the vigor of the trees indirectly gives them greater power to resist disease. This fact was strikingly illustrated in the inoculation experiments with nursery stock where it was found that the trees that were making a feeble growth were far more susceptible to the action of the fungus than those which were making a vigorous growth.

Usually but little attention is given to slight wounds that are made here and there on the trees, but it should be remembered that a majority of cankers start from some mechanical injury. Too much care cannot be exercised not to wound or bruise the limbs when trimming the trees or picking the fruit. Wounds are frequently made by the chafing of ladders against the limbs or by the workman's boot when climbing through the trees. Serious wounds are also frequently made by propping the limbs when they are overloaded with fruit. The props should be padded or have the corners rounded where they come in contact with the limbs; they should be put in place carefully and not be driven under the limbs as is sometimes done. All wounds, whether accidental or made in trimming, should be protected with thick paint or grafting wax.

Cankered limbs should be cut out wherever practicable, or in some cases it may pay to cut off the diseased bark and cover the wounds as recommended above. Then as a preventive measure we feel warranted in recommending thorough spraying with Bordeaux mixture, giving the first treatment before the leaf-buds open in the spring, followed by the three sprayings that are usu-

ally given the trees for apple scab. Great pains should be taken to see that the limbs are thoroughly protected with the mixture as well as the foliage and fruit. The approximate dates of spraying may be given as follows: 1. About the time the leaf-buds begin to open. 2. About a week before the blossom-buds open. 3. As soon as all of the blossoms have fallen. 4. Ten days or two weeks after No. 3.

INVESTIGATIONS IN 1899.

It was originally planned that this season's work should be a verification of the previous year's results, namely, the identification of the canker fungus and the determination of its relation to what was thought to be the same species that occurs on pear and quince trees and on the fruit of all three species of trees. But the work broadened as *Sphæropses* were found on a variety of hosts representing seven orders of plants.

Since a knowledge of the host plants of any plant disease is of great practical value in order that it may be successfully combated, an attempt was made to determine the relation of the species of *Sphæropsis*, represented by the different hosts, to the canker fungus.

In the spring of 1898 specimens of blighted apple tree twigs were received from Odessa, N. Y. It was not determined at the time what was the cause of the blight but a subsequent examination revealed the presence of numerous pycnidia containing mature spores of a *Sphæropsis*. On visiting the orchard late in the fall, it was found that the twig blight had been quite noticeable in 1897, but there was none to be found on the current season's growth. In all cases noticed, when once attacked, the entire growth of the season had been killed and in a few instances the disease had extended into the previous season's growth. There were a few miniature canker spots on the smaller limbs but none were noticed on the larger branches and the trees were in a fairly vigorous condition.

Some pear trees growing in a door-yard about twenty-five rods distant from the orchard were pointed out as being in a dying condition, the top of one tree having been entirely destroyed while the other trees were half or two-thirds dead. The pycnidia of a

Sphæropsis were found to be very abundant on the dead bark, while a few black, shriveled pears that were still attached to the branches were attacked by the black rot fungus, *Sphæropsis malorum* Pk.

A *Sphæropsis* was also found on the twigs of a quince tree that grew by the side of the pear tree.

At a later date a canker was found on a quince tree in the Station orchards. The appearance of the cankers and their effect on the limbs was much the same as the canker of apple tree limbs, the swollen sections of limbs and the roughened bark at once attracting attention. The pycnidia of a *Sphæropsis* were abundant on the dead bark where the fungus had recently been in an active condition. This fungus was also found to be abundant in the large quince orchard of Maxwell Brothers, near Geneva. There were but few typical cankers on these trees, but in many instances there was a well defined longitudinal strip of dead bark on the limbs on which pycnidia of a *Sphæropsis* were abundant. It seems probable, however, that in such instances, as well as with the pear trees mentioned above, the fungus was following, but aggravating, former injuries.

Dilution plate cultures were made of the *Sphæropses* from the twigs of the three different host plants and after the fungus had fruited, fruits of the apple, pear and quince were inoculated with pure cultures of the fungus from each of the three hosts. The fruits were kept in closed glass jars, the check fruits punctured but not inoculated occupying jars by themselves. Black rot, *Sphæropsis malorum* Pk., was produced in each inoculated fruit while the checks remained sound. Usually there would be an area of decayed tissue around the points of inoculation in twenty-four hours, depending on the degree of ripeness of the fruit. The decay progresses rapidly in the ripe fruit ; in some instances the greater portion of the surface became brown, and mature spores of the fungus were formed in six days.

In the spring of 1899 a *Sphæropsis* was found on dead and dying Japanese plum trees at Riverhead, N. Y. Cultures were made of the fungus, and apple, pear, and quince fruits were inoculated. Black rot was again produced in the inoculated fruit while the check fruits remained sound.

These results led to an investigation of the local distribution of the genus *Sphæropsis*, when it was found to be widely distributed; as the list of host plants given in Tables I and II will show. Cultures were made of the *Sphæropses* from each host and apple, pear, and quince fruits were inoculated with cultures from each so far as the supply of fruit would permit. Three fruits at least, and in a majority of instances six, were inoculated with cultures from each host. Black rot was readily produced in the fruits, there being apparently no difference in the effect of the *Sphæropses* as obtained from the different hosts. The inoculated fruits as well as the checks were kept in closed glass jars, as before.

During the progress of the work it was noticed that in most cases there was but little difference in the average size of the spores as they occured on the different hosts. It was also found that when apple, pear, or quince fruits were inoculated with cultures of *Sphæropsis* from these hosts the resulting spores were larger and of the size of those found on fruits attacked by black rot. The series of spore measurements given in the table below was made to show the relation of the average size of the spores to the host on which they are grown. Since spores of *Sphæropsis* as they occur on any host vary greatly in size, even in the same pycnidium, an average of fifty measurements was taken in each instance.

Table I gives: (1) A list of hosts from which cultures of *Sphæropsis* were made; (2) average length of 50 spores as they occur on the hosts; (3) average length of 50 spores as they occur on apple, pear, and quince fruits when inoculated with cultures of *Sphæropsis* from the different hosts.

TABLE I.—SPORE MEASUREMENTS OF *Sphæropses* FROM DIFFERENT SOURCES AND ON DIFFERENT HOSTS.

Hosts from which cultures of *Sphæropsis* were obtained.	Average length of 50 spores as they occur on the host.	Average length of 50 spores produced on apple fruits inoculated with material from the different hosts.	Average length of 50 spores produced on quince fruits inoculated with material from the different hosts.	Average length of 50 spores produced on pear fruits inoculated with material from the different hosts.
Pear tree twigs........	22	30	29	26
Quince tree limbs.....	23	29	29	27
Apple tree limbs......	26	29	30	28
Japanese plum, *Prunus triflora* Roxb.......	28	30	30	30
Hawthorn, *Cratægus oxyacantha* L......	21	28		
Persimmon, *Diospyros virginiana* L	21	28		
Wild crab, *Pyrus coronaria* L............	21	28		
Sumach, *Rhus typhina* L..................	23	29		
Bitter sweet, *Celastrus scandens* L.........	22			
Apricot, *Prunus armeniaca* L.......	22	30		
Choke cherry, *Prunus virginiana* L......	21	29		
Hop horn beam, *Ostrya virginica* Willd, decorticated wood.....	22	28		
Mulberry, *Morus alba* L.............	21			
European plum, *Prunus domestica* L...	21	25		
Elder, *Sambucus canadensis* L...........	21	29		
Pear leaves...........	24	30		

The table is of interest in that it shows that the average size of spores of *Sphæropsis* varies according to the host on which they are grown. For instance the pycnidia and spores as they grow on pear wood are somewhat smaller than those that are found on apple wood, yet the spores produced on apple fruits inoculated with cultures from either host, are of the same size and character; similarly, though not shown in the table, when pear trees are inoculated with cultures of *Sphæropsis* taken from apple trees the resulting pycnidia and spores are of the average size of those found in nature on pear tree bark.

The spore measurements also show that in most cases there is but little difference in the average size of the spores of *Sphæropses* as they occur on the hosts under consideration. Those on apple and Japanese plum trees are the only ones where the average length is noticeably greater than the rest in the list. Cultures of *Sphæropsis* from either apple or Japanese plum trees when inoculated into apple, pear, or quince fruits produce black rot and as is shown in Table II these cultures grow interchangeably on at least four species of trees. In each instance the fruiting bodies resulting from the cross inoculations have the same characters as those that occur on the trees naturally.

Since cultures of *Sphæropses* from the different hosts produce black rot of fruit, one apparently as readily as another, it was to be expected that the different cultures would make similar growths when cross inoculations were made in the trees. Accordingly, apple, pear, plum, cherry, and quince nursery trees were planted in a plat on the Station grounds for inoculation experiments.

Dilution plate cultures were made of the *Sphæropses* from the different hosts and after spores formed, transfers were made to sterilized bean stems in test tubes. The inoculations were made by making a small incision in the bark with a flamed knife and inserting some of the pure cultures of the fungus from the test tubes between the bark and wood; then the wounds were covered with grafting wax. The work was done the last of May and first of June.

Table II gives the plan of the experiment together with the results; and shows: (1) Kind and number of trees inoculated and number of inoculations made in each tree; (2) source of cultures with which inoculations were made; (3) growth of fungus where inoculated.

TABLE II.—GROWTH OF *Sphæropsis* FROM DIFFERENT SOURCES ON DIFFERENT HOSTS.

Hosts from which cultures of *Sphæropsis* were obtained.	Apple Trees.		Pear Trees.		*Plum Trees.		Cherry Trees.		Quince Trees.	
	Each figure represents number of inoculations made in 1 tree.	Growth of fungus.	Each figure represents number of inoculations made in 1 tree.	Growth of fungus.	Each figure represents number of inoculations made in 1 tree.	Growth of fungus.	Each figure represents number of inoculations made in 1 tree.	Growth of fungus.	Each figure represents number of inoculations made in 1 tree.	Growth of fungus.
Pear tree twigs........	6	fair.	5	slight.	4	tree died.	None of these inoculations successful.		4	good.
	5	slight.	5	"	4	very good			4	slight.
	4	"	5	good.	4	slight.			4	"
	4	"	5	very good	4	"			4	fair.
Check..............	4	o	4	o	4	o			4	o
Quince tree limbs....	4	slight.	4	fair.	4	slight.			4	good.
	4	fair.	4	good.	4	"			4	slight.
	4	"	4	"					4	fair.
	4	slight.	4	"					4	good.
Check..............	4	o	4	o					4	o
Black rot of pear, *Sphæropsis malorum* Pk.	4	fair.	4	fair.		fair.			4	fair.
	4	"	4	very good	4	"			4	"
	4	"	4	slight.	4				4	"
	4	"	4	"					4	"
Apple tree limbs.....	4	very good	4	very good		good.			4	"
	4	"	4	"	4	"			4	good.
	4	"	4	"	4				4	"
	4	"	4	"					4	fair.

TABLE II.—*Continued.*

Hosts from which cultures of *Sphæropsis* were obtained.	Apple Trees.		Pear Trees.		* Plum Trees.		Cherry Trees.		Quince Trees.	
	Each figure represents number of inoculations made in 1 tree.	Growth of fungus.	Each figure represents number of inoculations made in 1 tree.	Growth of fungus.	Each figure represents number of inoculations made in 1 tree.	Growth of fungus.	Each figure represents number of inoculations made in 1 tree.	Growth of fungus.	Each figure represents number of inoculations made in 1 tree.	Growth of fungus.
Check..............	4	0	4	0	4	0	None of these inoculations successful.		4	0
Japanese plum, *Prunus triflora*, Roxb.......	4 4	very good "	4 4	very good fair.	4 4	good. slight.				
Hawthorn, *Cratægus oxyacantha* L......	4 4	fair. "	4 4	" "	4	very good				
Persimmon, *Diospyros virginiana* L........	4 4	slight. "	4 4	slight. "	4 4	0 0				
Wild crab, *Pvrus coronaria* L............	4 4	fair. "	4 4	good. fair.	4 4	0 0				
Check..............	4	0	4	0	4	0				
Sumach, *Rhus typhina* L................	4 4	fair. "	4 4	fair. "	4 4	0 0			6	0
Bitter-sweet, *Celastrus scandens* L..........	4 4	" "	4 4	" very good	4 4	0 0				
Apricot, *Prunus armeniaca* L.	4 4	" "	4 4	slight. "	4 4	tree died. fair.				

Check...............	4	o	4				None of these inoculations successful.			
Choke cherry, *Prunus virginiana* L........	4	good.	4	fair.	4	fair.				
	4	"	4	"	4	tree died.				
Hop hornbeam. *Ostrya virginica* Willd., decorticated wood.	4					very good				
	4	"			4					
		"			4	"				
Mulberry, *Morus alba* L..................	4	fair.			4	good.				
	4	"			4	very good				
European plum, *Prunus domestica* L.....	4	very good			4	o				
	4	"			4	o				
Elder, *Sambucus canadensis* L............	4	o								
	4	o								
	4	o								
	4	o								

*Part European and part Japanese plum trees were used in the experiment ; the inoculations were successful on the Japanese tree only.

The extent of growth of the *Sphæropses* where inoculated has been expressed in the relative terms, slight, fair, good and very good. Figures 1, 2 and 3 of Plate IV are reproduced from a photograph of inoculated nursery trees of apple, pear and Japanese plum respectively, and show what has been termed a very good growth. Figure 4 of Plate IV shows a slight growth on an apple tree, while Fig. 5 is a check apple tree. The other two degrees of growth range between the two shown in the illustration.

Where the fungus made a very good growth it spread rapidly till the different inoculations coalesced and formed continuous cankers as is shown in the illustration. In some instances pycnidia formed by the tenth of July and by the first of August growth had stopped as could be seen by the formation of a definite boundary between the dead and living bark. Pycnidia were now abundant on the dead bark and occasionally on the decorticated wood under the grafting wax as well as elsewhere on the dead surface. In some instances where the fungus made a less vigorous growth the area of dead bark was entirely covered with the wax.

A number of the different cultures were inoculated into all four kinds of trees, all but three into both apple and pear trees, while all were inoculated into apple trees. Twenty-five sweet and twenty-five sour cherry trees, and twenty-five European plum trees were also used in the experiment, but none of the inoculations on these trees were effective. In all of the other inoculations there were but two entire failures. But the inoculations made with cultures of *Sphæropsis* from cankered apple tree limbs made a greater growth than most of the others. Those made with cultures obtained from Japanese plum were the only ones which made a comparable growth.

The results of the inoculations on the pear trees are interesting from the fact that the cultures obtained from cankered apple tree limbs made a greater growth when inoculated into pear trees than the cultures did that were made from diseased pear trees.

Various other inoculations were made that are not given in the table, the details of which need not be entered into here; it may be said, however, that of something over 1,000 inoculations

made in 1899 very few gave negative results. Fig. 1 of Plate V shows an apple tree whose top is dead, the result of inoculations made with cultures of *Sphæropsis* obtained from sumach. It should be pointed out, however, that this particular branch was making a feeble growth, and that inoculations made in two of the side branches failed to grow. In several other instances where inoculations were made in weak trees the fungus made a much greater growth than it did in adjacent vigorous trees. This point is of great practical importance and confirms what has been said on this subject on a former page. Fig. 2 of Plate V shows a twig blight of pear and apple trees respectively, the result of inoculations made with cultures of *Sphæropsis* from cankered apple tree limbs in twigs of the current season's growth.

The results of the inoculation experiments tend to show that the number of species of *Sphæropsis* can be materially reduced. In some instances it appears that a new host has served as a basis for making a species, and since many of the hosts given in the table represent different species it would seem that this plan had been followed when some of these species were made. So far as the writer can determine there is but slight difference in the morphological characters of the species that are represented in the tables by the different hosts, such as might occur with any fungus when grown on different media or when transferred from one plant to another. Neither do the published descriptions of these species suggest any material differences.

A set of the *Sphæropses* on the different hosts was submitted to Mr. J. B. Ellis, Newfield, N. J., for identification with the published descriptions. His determination of the species so far as he was able from the specimens sent are given in Table III.

TABLE III. — PRESENT CLASSIFICATION OF *Sphæropsis* FOUND ON DIFFERENT HOSTS.

Pear tree twigs	*Sphæropsis* sp. Apparently same as on plum.
Quince tree limbs..................	*Sphæropsis cydoniæ*, C and E.
Black rot of apple, pear, and quince fruits	*Sphæropsis malorum* Pk.
Apple tree, bark	*Sphæropsis mali* (West.) Sacc.
Apple tree, decorticated wood......	*Sphæropsis cinerea* (C and E.) Sacc.
Japanese plum, *Prunus triflora* .	*Sphæropsis* sp.
Hawthorn, *Cratægus oxyacantha* L.	*Sphæropsisis demersa* (Bon.) Sacc.
Persimmon, *Diospyros virginiana* L.	*Sphæropsis* sp.
Wild crab, *Pyrus coronaria* L.....	*Sphæropsis*—New sp?
Sumach, *Rhus typhina* L...........	*Sphæropsis sumachi*(Schw.)C and E.
Bitter sweet, *Celastrus scandens* L..	*Sphæropsis celastrina* Pk.
Apricot, *Prunus armenica* L.......	Apparently same as on plum.
Choke cherry, *Prunus virginiana* L.	*Sphæropsis cerasina* Pk.
Hop hornbeam, *Ostrya virginica* Willd (decorticated wood)........	*Sphæropsis* sp.
Mulberry, *Morus alba* L......	*Sphæropsis mori* Berlese.
European plum, *Prunus domestica* L.	Same as on Japanese plum.
Elder, *Sambucus canadensis* L......	*Sphæropsis sambuci* Pk.
Pear leaves........................	*Sphæropsis mali* West., foliicolous form.

A discussion of the relation of these species will be out of place at this time. However it may be pointed out that the inoculation experiments prove that the species occurring on apple-tree bark, *S. mali*, and on decorticated apple-tree wood, *S. cinerea*, are the same; also that these species are identical with the black rot fungus, *S. malorum*. Thus it will be seen that some interesting questions in nomenclature are involved. Which of these names should stand, if either, or whether they will all prove to be synonyms can only be determined after a careful study of the entire genus is made.

In former papers by the writer referred to on page 181 mention was made of the fungus, *Sphæropsis malorum* Pk., as being the probable cause of the New York apple-tree canker. It is therefore suggested that this name be retained for the present in order that still further confusion in nomenclature may be avoided.

BODY BLIGHT OF PEAR TREES.

In the spring of 1898 when the preliminary studies with apple canker were begun a few inoculations were made in the larger limbs of a pear tree with cultures of *Sphæropsis* obtained from cankered apple-tree limbs. The details of the experiment are given on page 184. The fungus grew readily at all points of inoculation and though the culture material was inserted between the the bark and wood it did not attack the cambium layer but made its growth in the outer bark. Here dead sunken areas were produced similar to those that are so common on the trunks and larger limbs of pear trees. These definitely outlined and sunken areas of dead bark commonly known as body blight, have long been thought to be due to the action of the pear blight bacillus; however, there seems to be no definite reason for such belief.

But little attention was given the matter at the time since it was not then known that *Sphæropsis* occurred on these blighted areas. In the spring of the present year, however, a *Sphæropsis* was found to be comparatively abundant on the diseased bark of pear trees in the Station orchards. Since that time a large number of pear trees from many localities affected with body blight have been examined and in nearly every instance a *Sphæropsis* was present though not in sufficient quantity to account for many of the blighted areas. *Macrophoma malorum* (Berk.) Berl. et Vogl. is commonly present in large quantities on the dead bark and since *Sphæropsis* is able to produce body blight may not this closely related fungus be an important factor in producing the deceased condition?

Fifty successful inoculations made this spring with cultures of *Sphæropsis* in mature pear trees confirm last year's results. An attempt was also made to grow the *Macrophoma* artificially but it made an indifferent growth on all of the media that were tried and produced no fruit, consequently inoculation experiments with this fungus could not be undertaken at that time.

THE PACIFIC COAST APPLE-TREE CANKER.

After the publication of the paper, An Apple Canker, the writer received inquiries concerning the canker from the secretaries of horticulture respectively of Oregon, Washington and British

Columbia. These gentlemen sent specimens of diseased limbs which upon examination were found to be attacked by an entirely different fungus from the one that causes the New York canker, the spores were small, curved and hyaline while the spores of *Sphæropsis* are large, oval and dark brown in color. A liberal number of specimens were received from each of the three sections and the fungus was the same in each case and so much in evidence that there can be little doubt but that it is the cause of the Pacific coast canker. Some of the specimens were submitted to Prof. C. H. Peck, State botanist who pronounced the fungus to be a new species of *Macrophoma*. This disease because of its destructive nature has attracted a great deal of attention for a number of years in the Pacific Coast States, but no satisfactory method of combating it has yet been found. Since entirely different climatic conditions obtain in that part of the country it is not likely that the line of treatment recommended for combating the New York apple canker will be effective against this disease as it occurs on the Pacific coast.

Fig. 1 of Plate VI is from a photograph of an apple-tree limb showing a typical specimen of the Pacific coast apple-tree canker.

THE EUROPEAN CANKER.

Fig. 2 of Plate VI shows a canker on a quince tree limb which was produced by the fungus, *Nectria cinnabarina* (Tode.) Fr. This shows what is known as the tubercularial or conidial stage of the fungus ; what appear as small white bodies in the picture scattered over the surface of the dead bark, are brilliant red or cinnabar colored stromata which bear the conidia or fruiting bodies of one stage in the life history of the fungus. It will be seen that the comparatively large size and brilliant color of the stromata render the fungus conspicuous so that it is not easily mistaken.

Another species, *N. ditissima* is the common canker-producing fungus of the orchard trees in many parts of Europe. Neither of the species is sufficiently abundant in the orchards of the United States to be regarded as a pest.

The illustration in Plate VI, fig. 2 is from a photograph of one of a few quince tree limbs attacked by *N. cinnabarina* that

were found in the quince orchard of T. C. Maxwell and Brothers, Geneva, N. Y.

ACKNOWLEDGMENTS.

It is with pleasure that I acknowledge my indebtedness to Prof. Beach, at whose earnest request this work was undertaken, and to whose kind consideration its completion was made possible. To Dr. Thaxter I am indebted for advice on the question of nomenclature and to Mr. Ellis for the determination of species.

EXPLANATION OF PLATES.

PLATE I. Fig. 1.—*A cankered apple tree limb, wood exposed at* a *and white fruiting bodies of* Schizophyllum commune *Fr. are conspicuous on the dead bark. A canker of more recent formation is shown at* b.

Fig. 2.—*The same limb as in Fig. 1 with the dead bark removed.*

Fig. 3.—*A larger view of the small canker shown at* b. *The surface is thickly dotted with pycnidia.*

Fig. 4.—*Small section of dead bark from canker in Fig. 3 showing pycnidia natural size.*

PLATE II.—*Different forms of cankers. Fig. 1 shows limb that for more than six feet is covered with rough bark, or scars where bark has become detached; fungus has reached cambium at* a.

PLATE III. Fig. 1.—*Apple tree bark inoculated with cultures of* Sphæropsis *from cankered apple limbs. Inoculations were made in the outer bark; the fungus was unable to reach cambium but made small wounds in the outer bark. Where the bark has been removed the scars resemble those shown in Fig.* 2.

Fig. 2.—*Section of limb shown in Plate II, Fig. 1, enlarged to show scars more in detail.*

Fig. 3.—*Limb of a large appple-tree inoculated in spring of 1898 with culture of* Sphæropsis *from cankered apple tree limb. Photographed fall of 1899. The canker enlarged materially during the present season. Pycnidia of* Sphæropsis *are abundant on dead bark and decorticated wood.*

PLATE IV—*Inoculation experiments with nursery stock.*

Fig. 1.—*Apple tree inoculated with cultures of* Sphæropsis *from cankered apple-tree limbs, showing what was designated "a very good" growth of the fungus.*

Fig. 2.—*Pear tree inoculated with cultures of* Sphæropsis *from cankered apple tree limbs, showing very good growth of the fungus.*

Fig. 3.—*Japanese plum tree inoculated with cultures of* Sphæropsis *from decorticated wood of hop hornbean. Very good growth of the fungus.*

Fig. 4.—*Apple tree inoculated with cultures of* Sphæropsis *from pear twigs, showing slight growth of the fungus.*

Fig. 5.—*Check apple tree; punctured but not inoculated.*

PLATE V. Fig. 1.—*Young apple tree, top branch killed by inoculating with cultures of* Sphæropsis *from sumach.*

Fig. 2.—*Twig blight of pear and apple respectively caused by inoculating with cultures of* Sphæropsis *from cankered apple tree limbs.*

Fig. 3.—Quince inoculated with cultures of Sphæropsis *from cankered apple tree limbs.*

PLATE VI. Fig. 1.—*Apple tree limb showing Pacific coast apple tree canker*

Fig. 2—*Quince tree limb showing canker caused by attack of* Nectria cinnabarina. (*Tode.*) *Fr.*

Plate I.

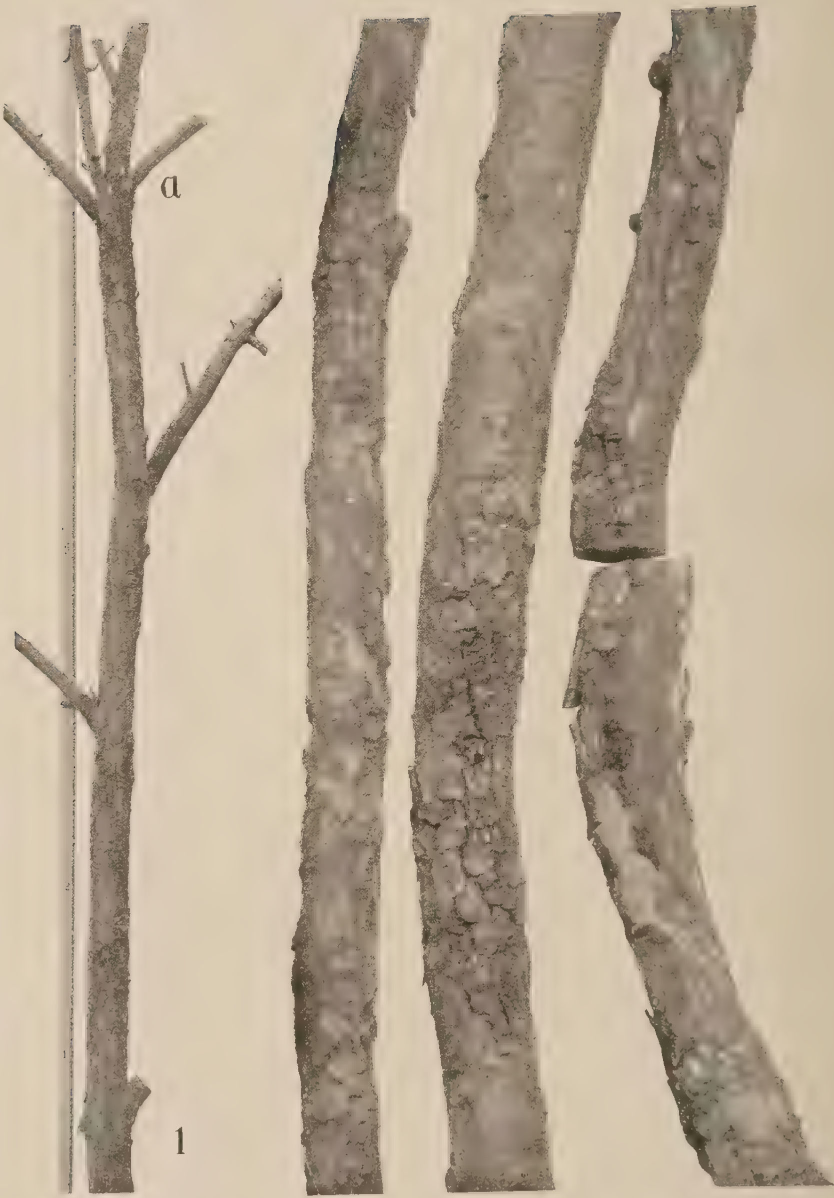

Plate II.

PLATE III.

PLATE IV.

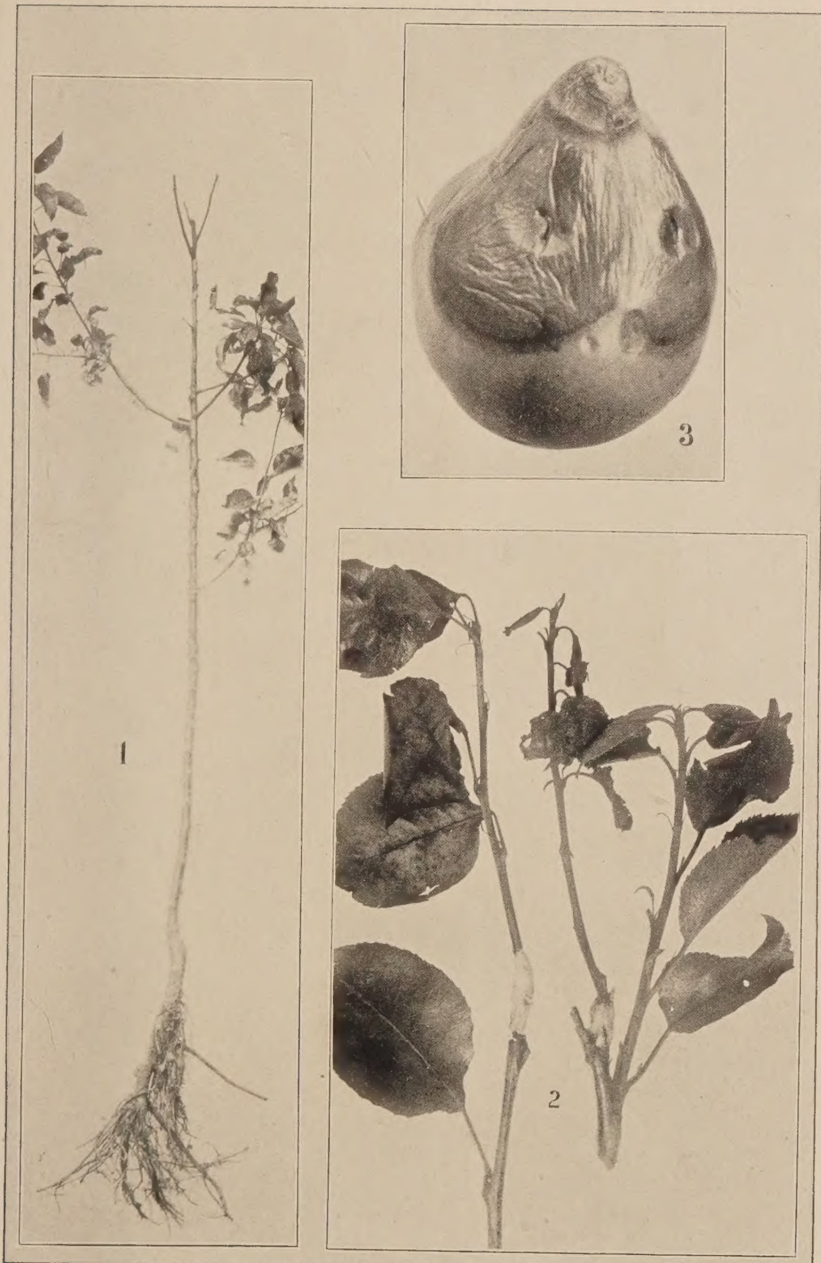

PLATE V.

PLATE VI.